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COMPARISON OF LIQUID DESICCANTS FOR AIR COOLING SYSTEMS USING WETTED WALL COLUMN

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ABSTRACT

Desiccant dehumidification refers to the use of chemical for absorption of water vapor to dehumidify air, and thus reduce the latent cooling load in a building's Heating, Ventilation and Air-Conditioning system. There are two types of desiccant systems: liquid and solid. Liquid desiccant systems remove more moisture from air than the dry desiccant systems. Some of the commonly used liquid desiccants include lithium bromide and lithium chloride. The paper presents a comparative analysis of three desiccants, namely, calcium chloride, lithium chloride and potassium formate. Calcium chloride and lithium chloride are commonly used whereas potassium formate is a new desiccant. The wetted wall column is used to study the dehumidifying property of each chosen desiccant. The gas enters in a counter-current fashion allowing gas-liquid contact. The analysis is used to understand the variations in the dehumidifying nature of the desiccants.

***KEYWORDS:** Wetted Wall Column, Liquid Desiccants, Potassium Formate, Calcium Chloride & Lithium Chloride*

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Original Article

1. INTRODUCTION

Increasing demand of comfort and an increase in world population has become a major global environmental issue. An enormous amount of greenhouse gases are released because of the combustion of fossil fuels. There has been an increased emission of carbon dioxide due to commercial development and an increase in population. The primary sources of energy are being consumed more than renewable and environment friendly energy resources. The increased emission of CO_2 and other greenhouse gases causes global warming.[1]

Dehumidification refers to the process of removing moisture from the air without altering its dry bulb temperature. When air at the given temperature is cooled below the dew point temperature, cooling and dehumidification occur at the same time. The commonly used air cooling systems use refrigerants that release greenhouse gases and harmful components like chloro-fluoro-carbons and hydro-chloro-fluoro-carbons. An alternative is to make use of desiccants.[2-6].

1.1. Desiccants

A desiccant is a hygroscopic substance that has an affinity to remove moisture from the surroundings [7]. There are two main types of desiccants: solid and liquid. Silica gel, titanium silicates, alumina are common examples of solid desiccant. Examples of liquid desiccants include lithium chlorides, tri-ethylene glycol and lithium bromide [8]. Other types of desiccants include polymeric desiccants, compound desiccants, composite desiccants and organic based desiccants. Some of the desiccant systems include solid packed tower, liquid spray

tower, rotating desiccant wheel and falling film column [9].

1.2. Liquid Desiccants

A liquid desiccant based cooling system consists of two main units, the absorber and the regenerator[10]. The dehumidifying action takes place in the absorber and the regenerator is used to remove moisture from the weak desiccant in order to reuse it. Aly et al. conducted a comparison between lithium chloride (LiCl) and calcium chloride (CaCl2) solutions applied as the desiccant solutions in the study. Potassium formate is a new desiccant [11]. Along with dehumidifying, a liquid desiccant system also provides cooling action due to the desiccant phase. A liquid desiccant system also allows easy integration of a solar collector for regeneration. These properties make a liquid desiccant system a better option when compared to a solid desiccant system. A lot of research has been done in order to find the low regeneration temperature of weak desiccant solution and studies have been conducted in order to optimize the liquid desiccant evaporative cooling systems [12].

1.3. Falling Film Column

A wetted wall or falling film column is equipment used to provide a platform for heat and mass transfer between two fluids. It consists of a vertical tube, through which the fluids flow in a counter current manner. The name falling film is given due to the formation of a thin film like coating of the liquid flowing down the vertical tube. This equipment is used as laboratory equipment because of the simplicity in modelling and operation. The wetted wall column can also be used to obtain correlations between Sherwood number, Reynolds number and Schmidt number by using a liquid phase and a gas phase medium. The reason why this equipment is not used in a large scale set up is, because of the low surface area and the hold-up of liquid when compared to other types of contractors.

2. MATERIALS AND METHODS

A wetted wall column consists of a vertical tube, through which the liquid desiccant flows downwards. The air flows into the tube, coming in contact with the flowing film. The advantages of using the tube in this equipment are that a low pressure drop is provided with high contact per unit volume. The equipment is also relatively more economical when compared to other type of contactors like plate column or packed column. The only concern is to be able to achieve a uniform, thin film over the cross section of the tube. [13]

Figure 1: Wetted Wall Column Set Up

A heater is provided to heat the inlet air, in order to maintain the system temperature. Any heat loss is prevented by insulating the pipeline. The liquid flow rate is controlled by a rotameter. The flow rate of air is measured using a manometer. A blower is used to prevent any over-heating of the wetted wall column. When the project deals with chemical substances in their vapor form, the vapors are allowed to flow from the storage tank, a blower is required to help mix the vapor with air.

The liquid desiccant is filled in the open overhead tank, and is fed to the column at a rate at which complete wetting with least possible ripple materialization is observable. Three desiccants have been checked in the wetted wall column, namely lithium chloride (35% concentration), calcium chloride (40% concentration) and potassium for mate (70% concentration). The heater is then switched on to heat the air that is to enter the column. A blower is provided to prevent the column from getting over-heated. Once the required inlet air temperature is reached, air is allowed to enter the column. The air flow rate is measured with the help of a manometer. Different trials are performed by changing the flow rates of air and desiccant. For each run, the hot air inlet temperature, liquid desiccant inlet temperature and liquid desiccant outlet temperatures are measured. Both the dry bulb temperature and wet bulb temperature at the air inlet and air outlet are to be measured. These temperatures are used to determine the percentage relative humidity of the air at the entrance and exit.

3. RESULTS AND DISCUSSION

In the tables below,

T1 = Air inlet temperature in °C

T2 = Desiccant inlet temperature in °C

T3 = Desiccant outlet temperature in °C

T4 = Temperature drop of air in °C

3.1. For Calcium Chloride Desiccant, the Following Results Were Obtained

Table 1: Experimental Observations Using Calcium Chloride Desiccant

Trial	T1 (°C)	T2 (°C)	T3 (°C)	Dry Bulb Air (°C)	T4 (°C)	Wet Bulb Air (°C)	Volume (ml)	Time (s)	Desiccant Flow Rate (ml/s)
1	39	28.8	33.8	32	7	25	61	100	1.64
2	42	29	32	30	12	24	36	100	2.78
3	55	28.8	33.3	31	24	24	23.96	100	4.17
4	60	28.8	34	32	28	24	20	100	5

Relative Humidity (%)	Pws (kPa)	Pw(kPa)	Absolute Humidity (g/m³)
42	5.1	1.63	11.59
40	4.4	1.76	12.58
20	4.8	0.96	6.84
18	5.1	0.91	6.52

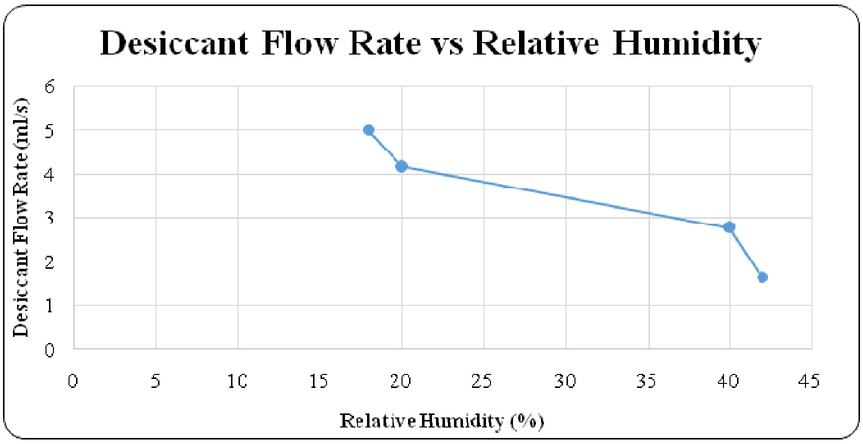

Figure 2: Desiccant Flow Rate Vs Relative Humidity of CaCl2

From the above tables and graphs, it can be inferred that calcium chloride can be used as a dehumidification agent, effectively. It can be observed that decrease in relative humidity is directly proportional to the running time. Errors in the above results can be due to improper control of flowrates and measurement.

3.2. For Lithium Chloride Desiccant, the Following Results Were Obtained

Table 2: Experimental Observations Using Lithium Chloride Desiccant

Trial	T1 (°C)	T2 (°C)	T3 (°C)	Dry Bulb Air (°C)	T4 (°C)	Wet Bulb Air (°C)	Volume (ml)	Time (s)	Desiccant Flow Rate (ml/s)
1	47.6	31	31.4	29	18.6	26	100	39.24	2.54
2	52.6	31.7	31.4	30	22.6	25	100	29.25	3.41
3	60.7	30	32.5	30	30.7	26	100	20.79	4.81
4	66.3	30	32.3	30	36.3	28	100	12.71	5.98

Pws (kPa)	Pw(kPa)	Absolute Humidity (g/m³)	Relative Humidity (%)
2.45	3.5	25.02	70
0.92	2.2	12.11	42
0.74	1.9	10.45	39
0.64	2	11.04	32

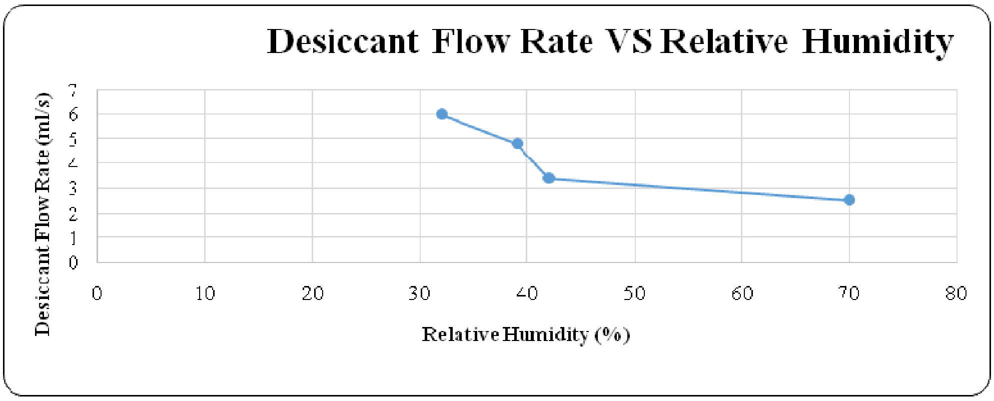

Figure 3: Desiccant Flow Rate Vs Relative Humidity of LiCl

Lithium chloride is the most commonly used desiccant. It can be observed that decrease in relative humidity is directly proportional to the running time. Errors in the above results can be due to improper control of flowrates and measurement.

3.3. For Potassium Formate, the Following Results Were Obtained

Table 3: Experimental Observations Using Potassium Formate Desiccant

Trial	T1 (°C)	T2 (°C)	T3 (°C)	Dry Bulb Air (°C)	T4 (°C)	Wet Bulb Air (°C)	Volume (ml)	Time (s)	Desiccant Flow Rate (ml/s)
1	74	29.5	35.7	32	42	25	100	30.54	3.27
2	68.8	29.5	35.3	31.5	37.3	24.5	100	23.89	4.18
3	63.2	28.5	35.3	31	32.2	24.5	100	16.75	5.97
4	59	28.5	34.8	30.5	28.5	24	100	14.54	6.87

Relative humidity (%)	Pws (kPa)	Pw(kPa)	Absolute Humidity (g/m³)
34	4.7	1.6	11.36
37	5	1.85	13.16
38	5.26	2	14.25
40	5.15	2.06	14.72

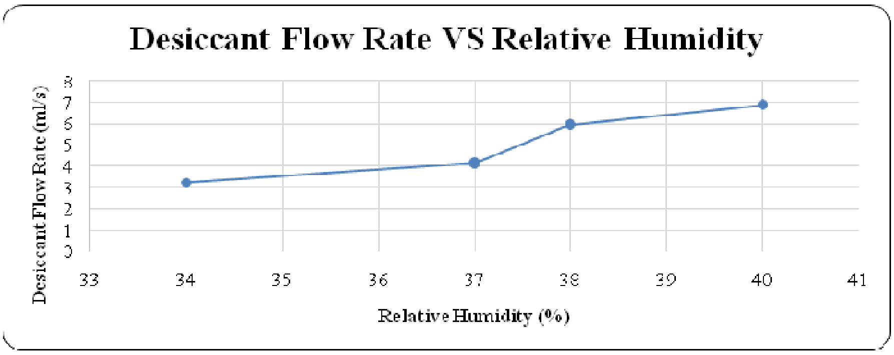

Figure 4: Desiccant Flow Rate Vs Relative Humidity of HCOOK

Potassium formate is a relatively new desiccant, not much study has been done on it. The first graph shows that lower relative humidity values can be obtained by maintaining lower desiccant flowrates. Errors in the above results can be due to improper control of flowrates and measurement.

3.4. Comparison of Relative Humidity Values with Time

Table 4: Comparison of Relative Humidity with Running Time

Trial	Time (s)	Relative Humidity (%)		
		$CaCl_2$	LiCl	HCOOK
1	300	42	70	34
2	600	40	42	37
3	900	20	39	38
4	1200	18	32	40

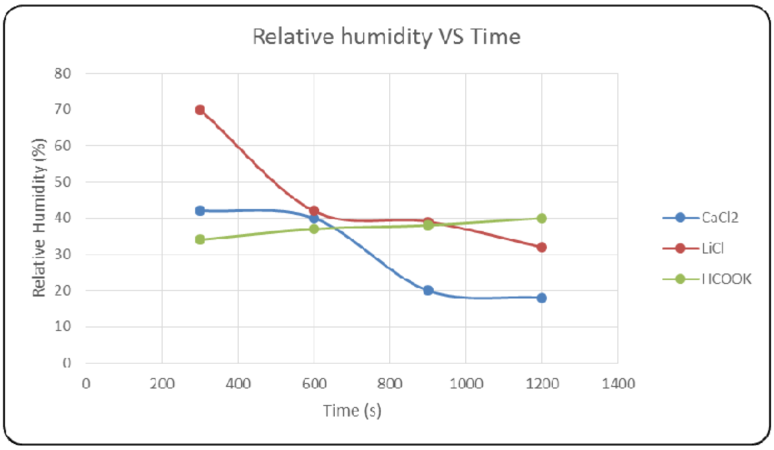

Figure 5: Relative Humidity VS Time

The above graph shows the dehumidification property of the three desiccants with respect to time. Though calcium chloride and lithium chloride show a decrease in relative humidity, potassium formate has been chosen because it is less corrosive than the rest. It has been studied that potassium formate's regeneration capabilities are better than lithium chloride and calcium chloride.

4. CONCLUSIONS

High levels of humidity have undesirable impacts on working spaces like mould growth, odour, corrosion and damage to the internal structure. The orthodox way of latent heat removal is through water vapour condensation by decreasing the air temperature by making use of vapor compression equipments. Conversely, these conventional methods are related with high electrical energy intake. Desiccant dehumidification is the best alternative as it reduces consumption of primary energy resources and is environment friendly. A liquid desiccant based dehumidifying system is more compact and has better mobility and regeneration temperature when compared to a solid desiccant based system.

After doing the above experiments, it was observed that potassium formate though takes more time to achieve lower relative humidity but it takes lower flowrate to achieve the same. Thus, potassium formate is a more economical desiccant as regeneration of the desiccant is easier. Potassium formate is also less corrosive in nature and reduces the problem of carry over. More research of potassium formate as a desiccant ought to be done.

A wetted wall column is the perfect setup for lab scale experiments to verify the dehumidifying property of desiccant. It provides with a higher area of contact per unit volume, which helps in better mass transfer.

From Figure(5), it can be observed that the three desiccants have similar values of percentage relative humidity at 600 seconds, 40% for $CaCl_2$,42% for LiCl and 37% for HCOOK. With increase in time a change in the trend can be seen, calcium chloride and lithium chloride show a decrease in relative humidity.

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